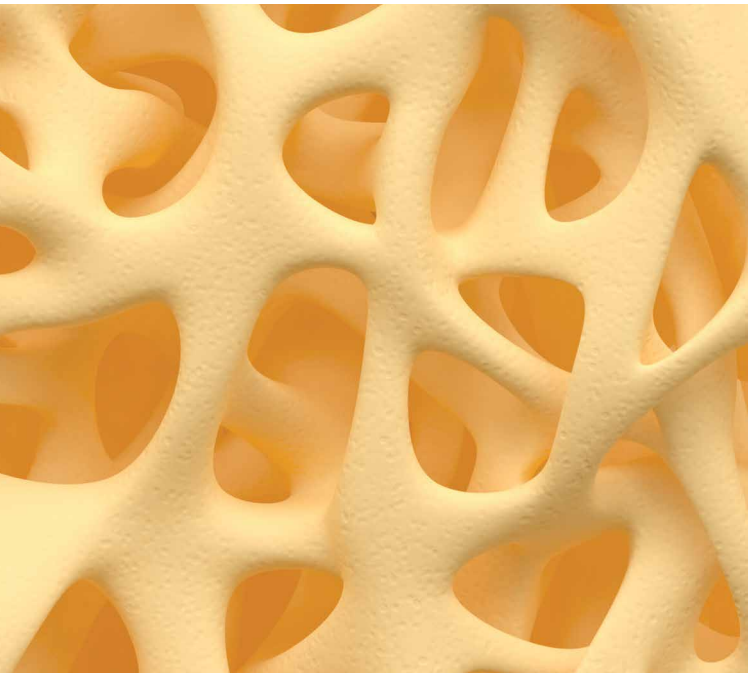


Count Down to the Future

Meg Cheng-Campbell
Ryan T. Scott
Samantha Torres
Matthew Murray
Eric Moyer



 Scientia

COUNT DOWN TO THE FUTURE

At the NASA Ames Research Center in California, the next generation of space biologists are working to understand the effects of long duration space flight on model organisms, and are developing ways to protect the health of future astronauts.

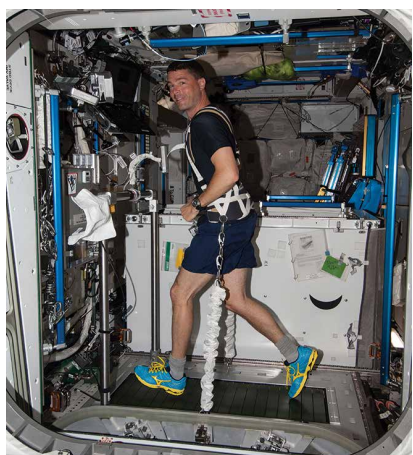
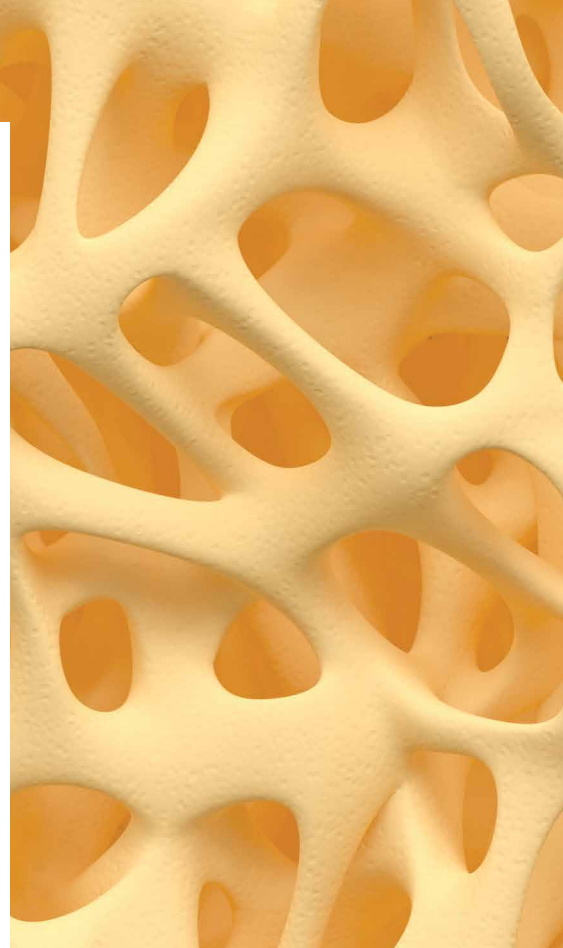
The human body has evolved over millions of years within an Earth-bound environment. The biomechanics of our cellular tissues are constrained by the physical laws of life on Earth. It is only within a tiny fraction of evolutionary time that we have developed the ability to leave our planet's protective atmosphere and experience the weightlessness of space. As we are developing our new-found potential for extra-terrestrial exploration, the consequences of placing human bodies into space long-term have to be carefully considered. At NASA Ames Research Center in California's Silicon Valley, a team of dedicated biologists is working to understand the effects of space flight on the human body, and is developing countermeasures to protect astronauts and colonists of the future as they embark on missions to other planets in our solar system.

NASA needs new scientists to be trained to continue this work into the future of space flight, and support the innovations in medical science that must accompany explorations of this kind. Dr Sanjoy Som, director of the Blue Marble Space Institute of Science, is a researcher at NASA Ames in the field of astrobiology – the study of the origin, distribution, and future of life on Earth and beyond. Alongside a team of other dedicated scientists, he has developed a unique training programme for early career scientists preparing to pursue postgraduate training. The programme gives students access to the cutting edge research environment, resources and expertise at NASA to develop projects aimed at supporting human life long-term in space. The programme also supports training in ethics and a consideration for the wider implications of their research projects. Science communication is also a big part of the training programme, helping future scientists and NASA to engage the public with current projects and ongoing research.

Living Bone

Bone is a dynamic living tissue that constantly adapts to the environment. The mechanical load on bone tissue acts to stimulate repair and regeneration to maintain a constant level of mineral content and mass. This process of remodelling occurs through bone resorption by specialised cells called osteoclasts, and the formation of new mineralised bone tissue by osteoblasts. In space, under reduced gravity (microgravity), resorption of bone is stimulated, leading to a loss of bone mass similar to that seen in osteoporosis. Scientists at the NASA Ames Research Center are currently working to unlock the mechanisms behind this process, in order to find ways to prevent it from happening. Back here on Earth, this research has major implications for understanding the degeneration of bone that occurs in disease, or when mechanical stimulation is lost due to prolonged bed rest in hospital.

Meg Cheng-Campbell, working with Dr Elizabeth Blaber and Dr Eduardo Almeida within the Bone and Signaling Laboratory, enjoys the challenge and satisfaction of fundamental biology research. The team have previously found that mice, exposed to microgravity for 15 days on the space shuttle Discovery or 30 days on the Bion M1 mission, experienced a loss of bone mass. Because the cells that make up bone are continuously replaced by new cells, the team hypothesised that these losses may be caused by a decreased capability of the bone to renew its own cells. This suggests that being exposed to gravity stimulates the production of new bone forming cells. In space, this loss of cell-renewal ability is combined with an increase in bone loss, leading to a reduction in bone mass. The team's research has implications for other parts of the body that rely on a constant supply of new cells to repair and regenerate.



CREDIT: NASA



CREDIT: NASA

Ryan T. Scott is working with Dr Joshua Alwood to investigate the molecular mechanisms that lead to bone loss during weightlessness and how space radiation affects bone strength. Ryan further investigates the effects of weightlessness on the female reproductive system. He has a special interest in the study of exercise science and physiology. He is working with Dr Alwood to discover how increasing activity in the limbs, such as during exercise, can counteract the effects of weightlessness and radiation when undertaken together with drug treatments. Indeed, in the future, it may be possible to take such drug treatments to prevent the loss of bone mass, and so the team are also investigating the possible side-effects these treatments might have if taken over a long time.

Samantha Torres, also in the Bone and Signaling Laboratory, currently works with Dr Ruth Globus on a project to investigate the physiological, cellular and molecular responses of bone to simulated galactic radiation and weightlessness. This work has implications for ground-based health problems such as prolonged bedrest and radiotherapy. The team showed that exposure to similar total doses and types of ionising radiation as those predicted during long duration space exploration, results in the activation of molecular mechanisms related to inflammation, stimulates bone-resorbing osteoclasts, and promotes bone resorption. The researchers are finding ways to protect against ionising radiation, such as consumption of dried plums, which have anti-oxidant and anti-inflammatory properties.

It's in the Blood

In the Vascular Analysis Laboratory, Matthew Murray is working with Dr Patricia Parsons-Wingter on the vessel generation analysis (VESGEN) project. Every cell in the body requires a constant supply of energy for metabolism and immune support, through highly branched blood vessels. Each cell is no more than a fifth of a millimetre away from the smallest blood vessels (capillaries), while these tiny vessels are at least forty branch points away from the heart. The vascular fingerprint for each person or animal is unique, and constantly adapts to changes in the environment by adding and removing capillaries. The growth of new blood vessels is important in embryonic development and also the development of pathological tissue in cancer. This same process also occurs during an inflammatory response to injury, and is required for proper wound healing.

The Vascular Analysis Laboratory has developed a software system for rapid and accurate analysis of the vascular fingerprint of animals or humans, to allow a detailed investigation of how these blood vessel patterns can change during space flight. This will enable the team to observe how these changes might affect health or disease progression during long-term missions. This vascular signature gives an accessible and quickly measured read-out of the complex molecular and cellular signalling pathways that are initiated to promote remodelling and growth of new vessels in response to stress or injury. The team has already used similar techniques to look at the changes in blood vessels that occur in the retina during diabetes, which can lead to sight loss.

Matthew and the team are currently interested in how changes in blood vessels in the retina change during space flight, in order to understand a condition known as Vision Impairment and Intracranial Pressure syndrome, which can cause vision loss after long exposure to reduced gravity. The team hope to measure the remodelling of blood vessels in the retina by comparing images before and after astronauts take a trip to the International Space Station. This will aid development of effective countermeasures for astronauts, but also potential future treatments for patients on Earth with similar medical conditions.

Space Sex

The number of women becoming astronauts was much less than the number of men in the first few decades of space flight, but this is rapidly changing. In fact, the NASA astronaut class of 2013 had equal numbers of men and women. Eric Moyer is working with Dr April Ronca to explore how space flight might affect the physiology of males and females differently, with the aim of improving the health of all astronauts travelling beyond our planet. They are investigating how to protect reproductive health, so that communities in space might adapt to conception, pregnancy, birth and development. They are also investigating the longer-term implications of how child development might be affected by exposure to the harsh environment and stresses of space flight.

Recent research has shown that mice who have spent weeks in space experience a disruption to their reproductive health and a loss of fertility. But this is only part of the problem. Technology for mouse studies in space has been developed at the Ames Research Center, allowing Eric and Dr Ronca to now analyse the effects of space flight on mouse behaviour, which can inform all future studies involving mammals in space. Remarkably most behaviour such as eating, drinking and grooming was very similar to the mice on the ground, but mice in space quickly learned to propel themselves around the habitat, with their activity levels actually increasing over time in flight. The development of these mouse habitats in space allows the team to research the effects of space flight on mammalian behaviour –



which needs to be addressed before more complex intergenerational experiments can be attempted.

This is important because the team's future experiments will investigate how radiation and reduced gravity conditions unique to space flight might affect the reproductive cycles of adults and also the development of offspring. They will be looking to expand past research investigating the effects of altered gravity, such as that seen during a space flight launch, on foetal development via patterns of gene expression and the maturity into adulthood, which has demonstrated a strong influence on health and disease throughout life. The goal will be to identify which environmental factors lead to changes in gene expression across the entire lifespan and how these factors may be transmitted to subsequent generations. For men and women to live beyond our planet and start forming communities, there is a lot to be understood about how life in space might affect the conception and development of offspring.

Ready to Launch

Meanwhile in the Biomodel Performance Laboratory led by Dr Sharmila Bhattacharya, students Iman Hamid and Christina Cheung are busy preparing their payload for an upcoming launch. Dr Bhattacharya's team are using fruit flies to explore how life in space alters the immune response to a microbial infection. They are also using software and video tracking to observe changes in fly behaviour. By comparing results from flies that have been to the International Space Station with flies back on Earth, they plan to look at a number of physiological processes important for future space travel, such as the roles that different genes play in protecting against reactive oxygen species and radiation.

The new rodent and fruit fly facilities on the International Space Station, combined with the biological research on the ground, allows this group of young scientists to gain unique hands-on research



CREDIT: NASA

experience and to develop new strategies for long range exploration and colonisation of our solar system. The opportunity to take part in these projects is preparing these future leaders to accomplish dizzying heights.

Meet the researchers



Meg Cheng-Campbell

Margareth 'Meg' Cheng-Campbell is currently a Master's student at Santa Clara University studying Bioengineering. Meg was introduced to NASA Ames Research Center as a Research Associate through the Space Life Sciences Training Program, where she worked with the Human Performance Centrifuge. Since then, Meg has worked with Dr Eduardo Almeida and Dr Elizabeth Blaber in the Bone and Signaling Laboratory. Her current work focuses on understanding the complex mechanisms underlying bone tissue maintenance and stem cell regeneration.

E: margareth.a.cheng-campbell@nasa.gov



Matthew Murray

Matthew Murray graduated from Santa Clara University with a Bachelor's degree in Bioengineering. He is currently working with Dr Patricia Parsons-Wingenter in the Vascular Analysis Laboratory at the NASA Ames Research Center on diabetic retinopathy, bed rest, and crew member studies. This forms part of the vessel generation analysis (VESGEN) project, which aids in determining the cause of Vision Impairment and Intracranial Pressure syndrome – a condition causing visual impairments often experienced after long-term exposure to microgravity.

E: matthew.c.murray@nasa.gov



Ryan T. Scott

Ryan T. Scott is a Research Associate at NASA Ames Research Center within the Bone and Signaling Laboratory working with Dr Joshua Alwood. His research seeks to investigate the molecular, cellular, biomechanical, and physiological effects of spaceflight, to understand how the musculoskeletal system, reproduction, endocrinology and nervous system are all impacted together. His future work is focused on development and testing of countermeasures to enable long-term spaceflight missions.

E: ryan.t.scott@nasa.gov



Eric Moyer

Eric Moyer is a biology researcher and lab manager for Dr April Ronca at the Reproduction and Development Laboratory at the NASA Ames Research Center. His research is focused on the molecular biology of rodent gene expression and the serum proteins produced within stress and metabolism regulation pathways following ground-based models of spaceflight exposure. He contributes to the study of animal behaviour on the International Space Station conducted using NASA's Rodent Research Facility.

E: eric.l.moyer@nasa.gov



Samantha Torres

Samantha Torres is a graduate student at San Francisco State University. She is currently studying for a Master's degree in Public Health with an emphasis on Epidemiology. She is also a Research Associate in the lab of Dr Ruth Globus at NASA Ames Research Center, where she seeks to understand the effects of radiation and microgravity on the skeletal system. Her research is focused on human biology in space and the effects of comparable conditions such as radiotherapy and musculoskeletal disuse here on Earth.

E: samantha.m.torres@nasa.gov

FUNDING

National Aeronautics and Space Administration – NASA